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ARPA Order No. 3344
Report Date December 1, 1978

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AN INTERACTIVE COMPUTER AIDING SYSTEM FOR GROUP DECISION MAKING

RANDALL STEEB
STEVEN JOHNSTON
ANTONIO LEAL
STEVEN LEVIN

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Prepared For:

Cybernetics Technology Office
Defense Advanced Research Projects Agency
1400 Wilson Boulevard
Arlington, Virginia 22209

PERCEPTRONICS

6271 VARIEL AVENUE • WOODLAND HILLS • CALIFORNIA 91367 • PHONE (213) 884-7470

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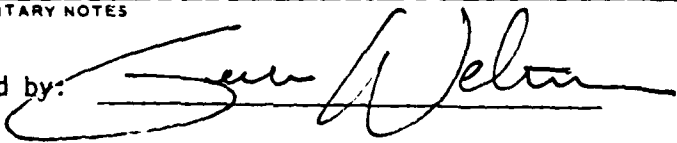
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report describes a program centered on the demonstration of an interactive computer aid for group decision making. The report includes: 1) Details of technical improvements made on the system; 2) Plans for experimental evaluations of the system, and 3) Description of a major system demonstration made at the Naval Air Development Center. The next phase of the program will concentrate on system evaluation studies and interfacing with the CACI executive aid.		

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1. SUMMARY

1.1 Report Period

The seventh quarter of contract activity involved (1) implementation of technical changes on the system, (2) development of plans for experimental evaluation of the system, and (3) demonstration of the system to planning groups at NADC. The following tasks were completed during the report period:

- (1) A series of important changes were made to improve system flexibility and speed, and to ready the system for experimental studies. Included in the modifications were: (a) algorithms for attribute definition and weighting, (b) tree traversing programs, and (c) a new set of conflict identification and resolution procedures.
- (2) Plans for a series of experimental evaluations have been finalized. The evaluations will center on determining the effectiveness of different procedures for conflict resolution and problem definition, and will examine the relative performance of aided and non-aided groups.
- (3) A full scale system demonstration was performed at NADC in Warminster, Pennsylvania. Several high level decision making groups were given an opportunity to use the system. Virtually all of the personnel were impressed with the aiding capabilities provided.

1.2 Next Period

The contract period during the next quarter will primarily concentrate on system evaluation studies. The specific items of work for the next period include:

- (1) Perform full scale experimental studies of system aiding.
- (2) Design system integration with CACI Executive Aid.
- (3) Continue cooperative effort with NADC to develop system design application.

1.3 Program Milestones

The milestone chart for the contract program is shown in Figure 1-1, with the report period illustrated as the shaded portion.

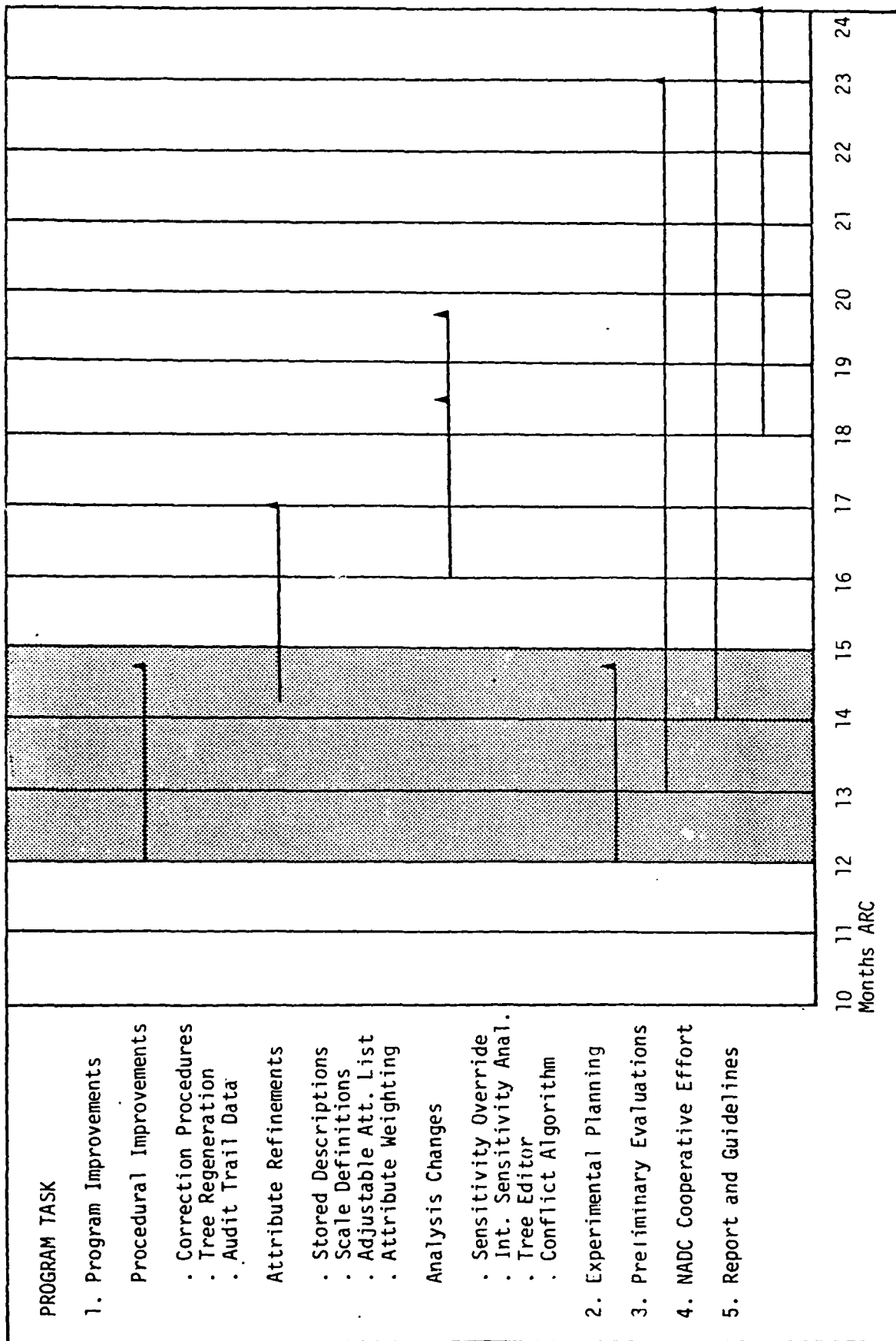


TABLE 1-1. PROGRAM MILESTONES

2. PROGRAM OVERVIEW

2.1 Statement of Problem

Constant escalation in weapons cost and effectiveness, as well as increasing complexity of international relations, makes military decision making more critical today than ever before. In today's military environment, most upper-level decisions are made by committees and staff groups. Typically, such groups contain experts from several speciality areas, who bring to the decision environment disparate sets of values. Decision time is usually limited, the decision making procedure is relatively unstructured, and intragroup conflicts arise on a broad variety of issues. Consequently the group is unable to consider the maximum set of alternatives, conflicts are not resolved in an optimum manner, and the resultant decision is rarely up to the aggregate potential of the group membership.

2.2 Rationale

Decision analysis offers a promising approach to solving these problems. The analytical procedure of building a decision tree formalizes the decision process, and permits incorporation of individual values (utilities) into the selection of alternative courses of action (Hays, O'Connor, and Peterson, 1975). However, decision analysis as it is usually practiced, is a highly personal and time-consuming process. Decision analysts are often called upon to assist in the solution of problems ranging over a large variety of domains. In most cases, the decision analysts know far less about the problem domain than do their clients. Thus, their contributions are confined primarily to the phases of formalization and optimization. While optimization is usually computer assisted, the formalization phase invariably has been accomplished

manually, using lengthy interviews of persons more familiar with the problem area. This approach is generally incompatible with the conditions of command group decision making.

Accordingly, it would be highly worthwhile to automate the formalization phase, using an interactive computer system to interrogate the group members and to construct a decision tree based on their responses. The purpose of the research undertaken here is to develop and evaluate the means by which such an interactive aid could be used to improve group decision making.

2.3 Objectives

The goal of the research program addressed in this progress report is to develop an automated decision tree elicitation system using on-line sensitivity analysis with direct real-time group feedback and evaluate its effectiveness in aiding group decision making.

The specific objectives of the current program include the following:

- (1) Develop computer programs for efficient, comprehensive, elicitation of decision trees from a decision making group.
- (2) Develop computer programs for identifying structural and numerical differences among the contributions of individual group members, for merging these contributions and for resolving the points of conflict.
- (3) Develop effective means for displaying to the group the results of the elicitation procedures and conflict analyses.

- (4) Integrate the various programs and techniques into a complete aiding system which can be readily transferred to other test environments.
- (5) Experimentally test the Group Decision Aid, using a variety of representative military decision problems, to demonstrate its advantages under realistic conditions of use.
- (6) On the basis of the developmental effort and the experimental results, establish guidelines and recommendations for future military applications of the group decision aiding methodology.

3. SYSTEM IMPROVEMENTS

3.1 Overview

The last quarter of activity involved completion of a number of system refinements and improvements. These improvements were necessary to ready the system for major experimental studies. Among the modifications made were changes to attribute definition and weighting procedures, the tree traversing program, the conflict identification and resolution algorithms, and the feedback options. The changes have led to greater generality, flexibility and speed of the system. Each of the improvements will be detailed in the following sections.

3.2 Attribute Definition and Weighting

A series of changes were made recently to facilitate the definition, scaling, weighting and revision of the attribute set. The specific procedures - selecting a "baseline" attribute, comparison of other attributes to this attribute, etc. - are detailed in the previous progress report (Leal, et al 1978). Preliminary tests of the procedures with groups at Perceptronics and at NADC (see section 5) resulted in the refinements listed below.

Two frames were found to be necessary for display of conflicts regarding attribute weights. A graphical display of normalized weights (in which $\sum w_i = 100$ for each participant) was found to be necessary to identify and rank conflicts (Figure 3-1). Following this frame a display of the raw weights (Figure 3-2) was found to best for re-entry of weight estimates, since the weights are again estimated in comparison to the baseline weight.

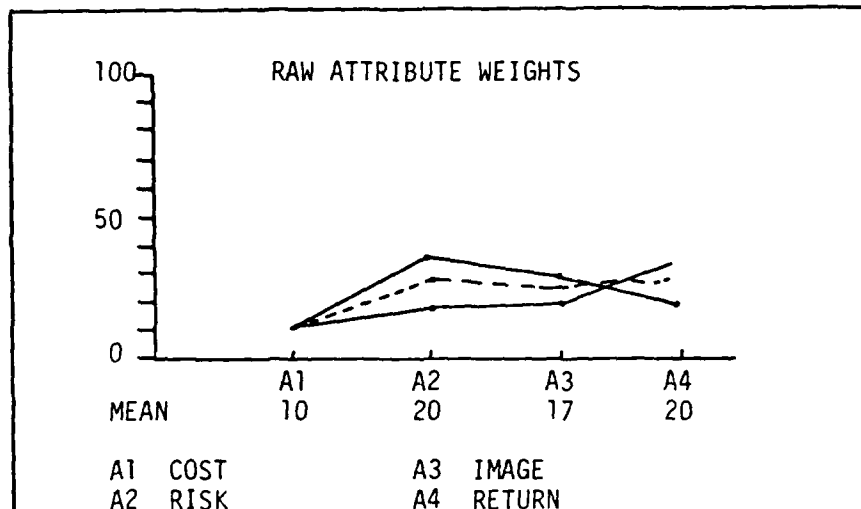


FIGURE 3-1. RAW WEIGHT CONFLICT FRAME

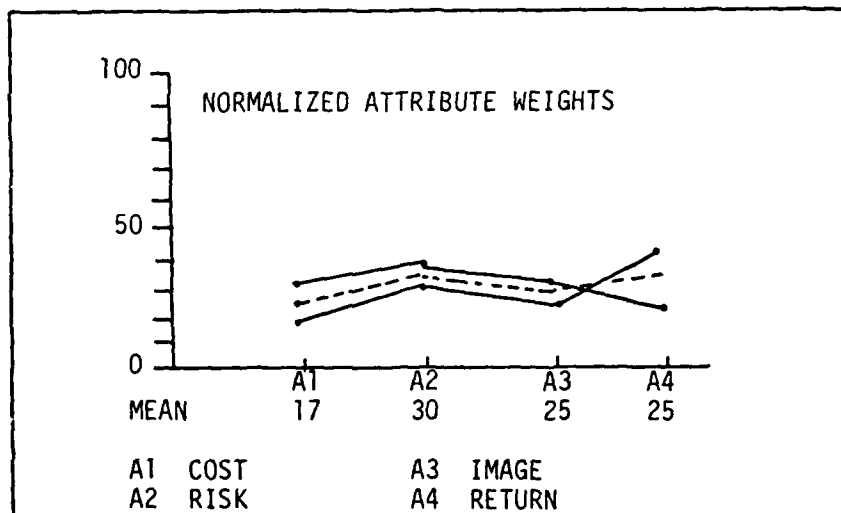


FIGURE 3-2. NORMALIZED WEIGHT CONFLICT FRAME

Some difficulties were noted at NADC regarding the procedures for revision of the attribute set. Frequent revision of the set of attributes was found to be time consuming and difficult. The problem appeared to be with the basic philosophy of definition of the attribute set, however, rather than with the procedures for revision. For example, several of the NADC groups defined different attribute sets for different portions of the tree. To be effective as a tool for evaluation, the attribute set should derive directly from the set of objectives for the problem. Each attribute should reflect the degree to which an alternative or outcome achieves a specific objective. Comparability across choices demands that the attribute set be invariant, or that changes in the set be incorporated in earlier evaluations. Subsequent tests of the system will include detailed instructions for the development and revision of the attribute set.

3.3 Tree Traversing

A tree traversing program was implemented to allow greater freedom in tree development. In particular this program allows override of the sensitivity analysis program regarding next node selection. The intermediary calls this program and moves through the tree to the desired node by pressing one of four directional buttons. The node may then be opened for probability and value estimation. The tree traverser may also be used to locate a node and delete the subtree extending from that node. This function is useful for redefining sections of the tree. An additional capability of this program is the display of the subtree from any selected node.

3.4 Conflict Resolution Algorithm

The original conflict identification and resolution algorithm was based on the degree of difference of opinion on each value estimate.

If the differences among the group were greater than a threshold amount, the MAU decomposition procedure was invoked. This procedure has been found to be effective but is somewhat arbitrarily based. For example, a large difference in estimated values for a given outcome may be present without a conflict regarding the preferred course of action. Conversely, a sub-threshold difference in values may actually produce a conflict at the root node.

A new conflict resolution program has been implemented. This algorithm identifies conflicts as those differences in values which cause a conflict in the initial decision. The sensitivity analysis program (also used for selecting the next node for expansion) tests each participant's values, one at a time. If a conflict is present, the node just opened is decomposed into attributes, and estimates of each attribute taken. After recombination, the overall values are again tested for conflicts at the root decision. If a conflict is still present, the multi-attribute procedure may again be called.

Using this procedure, conflicts can be identified at any point after the first level of the tree just as for the variability-based algorithm. In the first level itself, no provisional values are elicited. At the second and succeeding levels, each set of overall value judgements for a given node is rolled back to determine if a conflict is produced at the root node. If a conflict is present, the attribute level estimation frame cycles through each of the attributes one at a time. Once all of the attributes are estimated, the program determines the aggregated value for each participant by taking the weighted sum of attributes:

$$\text{value}_{jk} = \sum_i W_i A_{ijk}$$

attributes
i

Where V_{jk} is the overall value of action k to participant j , W_i the importance weight of attribute i , A_{ijk} is the level of attribute i associated with action k by participant j .

The conflict feedback display (Figure 3-3) is composed of the aggregated values for the participants still involved in a root-decision conflict. Instead of highlighting those attributes having high variance, the participants are shown the differences in level and the importance weights associated with each attribute. In this way, the participants can get an idea of how much each attribute actually contributes to the conflict in values. A subset of the attributes or the entire set may then be chosen for re-estimation. If a conflict is still present, the process may be repeated.

Several additional procedural options have been implemented for system flexibility. The group can invoke a multi-attribute decomposition even if there is no conflict in the overall value estimates. This is useful if the participants are uncertain as to the value of a complex outcome. Also, the value and probability estimates can be re-entered prior to the conflict testing should there be a mistake in input. A special display is provided in the case of the probability estimates. The group is displayed the mean and range of probability estimates and is allowed to re-enter if necessary.

The audit trail has been expanded to include information about the new conflict identification processes. A ranking and evaluation of alternatives by each participant will be taken at each decision node. Choices made at each point, such as display frames, actions, etc., will also be noted.

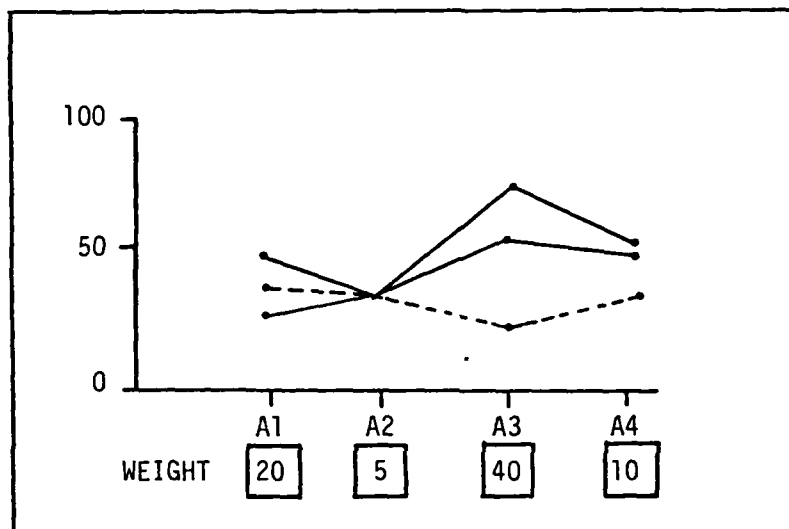


FIGURE 3-3. CONFLICT RESOLUTION FRAME

4. EXPERIMENTAL PLAN

4.1 Overview

A series of experimental evaluations of various aspects of the group decision aid have been planned. The experimental study will be directed toward the following major objectives.

- (1) To determine the relative effectiveness of alternative procedures for problem development and conflict resolution.
- (2) To determine the specific contributions to problem definition, conflict resolution and decision quality provided by the group decision aiding system.
- (3) To aid in development of guidelines and materials for system operation.

These objectives are planned to be accomplished through an experimental program based on performance comparisons between alternative system configurations and between aided and unaided group interaction.

4.2 Experimental Hypotheses

The experimental hypotheses deal with the aiding possible under various procedural options. The hypotheses are:

- (1) Use of a discussion and problem definition period prior to system use will result in less attribute redefinition and node deletion, greater overall tree complexity, and more confidence in the final recommendation than immediate use of aiding system.

- (2) The root decision conflict rule will result in a lower number of identified conflicts, greater tree development, and greater acceptance of the final choice than the variability-based rule.
- (3) The variability-based conflict identification algorithm will result in greater agreement and confidence in the final ranking of the decision options. The variability-based rule will also require less understanding of the aiding procedure than the root decision conflict rule.
- (4) Use of the group decision aiding system with either conflict resolution algorithm will result in greater speed, tree complexity, confidence in the final decision, and consideration of critical decision issues (as identified in the CACI analysis of the crisis scenario) than found with unstructured group performance.

4.3 Experimental Procedures

The scenario to be used for the evaluation will be the crisis scenario based on counter terrorist actions. This CACI-developed scenario has plausibility, reasonable complexity, numerous judgemental issues, and has been the subject of extensive analysis. Comprehensive measures of group participation, decision development, conflict resolution, and decision quality have been developed with respect to this scenario. A more detailed analysis of the scenario and the analysis measures are found in the previous progress report (Steeb, et al 1978).

Experimental Design

The experimental variables to be investigated include the following:

- 1) Form of conflict identification: Two levels, variability-based algorithm and root decision algorithm.
- 2) Group preparation: Two levels, use of group aid throughout problem and use of aiding system after preliminary, unstructured problem definition.
- 3) Presence of aiding: Two levels, use of group decision aiding system vs. unstructured group interaction.

The above conditions are sufficient for testing the experimental hypotheses and represent the primary system application issues at this point of development. The factors will be incorporated into a sequential experimental design, with one variable to be examined at each stage. The conditions included at each subsequent stage will be determined by the previous results. The variable of lesser importance, degree of group preparation, will be examined first. Following will be studies of aiding form and presence of the aiding system itself.

5. SYSTEM DEMONSTRATION

A full scale system demonstration was performed during the week of September 18 at NADC in Warminster, Pennsylvania. The intent of the demonstration was to familiarize Navy decision makers with the capabilities and operation of the system, and to provide a forum for further inputs regarding Navy needs.

The system was transferred to the PDP 11/70 at Warminster, and connected to their Advent projection system. This was accomplished shortly after completion of all of the changes described in Chapter 3 save for the new conflict resolution program.

Three groups worked with the system at NADC representing the Naval Air Development Center Management Center computer and software directorate, and project design group. Questionnaires administered following the demonstrations revealed the following reactions.

- 1) All respondents said that the system would help them make better decisions.
- 2) Most respondents felt that the system would not result in faster decisions, mentioning that the procedures for entry of probabilities and utilities were too time consuming.
- 3) Most felt that the procedures were easy to understand, although some practice time was necessary.
- 4) All participants were impressed with the nature and effectiveness of the group interaction.

In all, the participants saw many advantages in the system: explicit decision data, bookkeeping by the computer, systematic analysis, and aids to visualization and interaction. At the same time, needs for streamlining procedures and allowing revision of the inputs were identified. Several procedural changes, notable in the input processes, were made in the system in response to these suggestions.